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TITLE: REMOVAL OF EMBEDDED PARTICLES DURING CHEMICAL MECHANICAL POLISHING

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REMOVAL OF EMBEDDED PARTICLES DURING CHEMICAL MECHANICAL POLISHING

BACKGROUND

[0001] The present application relates generally to chemical mechanical polishing processes. More specifically, the present application relates to removal of embedded particles during chemical mechanical polishing.

[0002] Chemical mechanical polishing (CMP) is a commonly used technique for polishing semiconductor wafers. Semiconductor wafers are processed by a variety of chemical and thermal processes to define electronic circuits on or near the surface of the wafers. Some processes such as deposition of oxide or other layers form conformal layers across substantially the entire wafer surface. CMP is employed to convert the conformal oxide layer into a planar oxide surface. After deposition of the oxide but prior to the CMP process, the conformal oxide layer has a varied surface that matches the topography of the underlying layer, including steps and trenches in the underlying layer. The CMP process removes a portion of the oxide layer above the metal step, producing a substantially planar oxide layer. Subsequent layers deposited on the oxide layer will have a planar surface for deposition.

[0003] Conventional CMP processing involves polishing a wafer supported in a wafer-carrier head with a polishing pad mounted on a polishing platen. The wafer-carrier head is mounted on a polish arm or spindle. The wafer is held by the wafer-carrier head by a vacuum or other means during loading and unloading. During polishing, the polish arm moves to press the wafer surface against the polish pad with a predetermined force. Typically, both the wafer-carrier head and the polish table or polish platen rotate during polish. During CMP, a chemical slurry is maintained on the polishing pad. The slurry may include abrasive particles to modify the polishing characteristics of the polishing pad or to enhance polishing.

[0004] While conventional CMP processes result in excellent planarity and uniformity of the finished surface, contamination may result from the CMP

process. Contaminants such as the abrasive particles from the slurry, air bubbles in the oxide or particles of oxide itself may contaminate the surface of the wafer, becoming embedded in the surface. The result is a localized lack of planarity and non-uniform surface texture. The defects may be characterized as particle scratching, chatter marks or surface particles. When subsequent layers are deposited on the contaminated surface, the result is imperfections and reduced yield, which increases manufacturing cost.

[0005] One technique to reduce this sort of contamination has involved a final polish step with slurry or water to remove the contaminants. Alternatively, a brush cleaner has been used. A brush cleaner uses a porous sponge or brush made of material such as polyvinyl alcohol as the brushing element. The PVA material is soft and scrubs particles from the surface of the wafer without further damage to the surface material.

[0006] However, some sticky particles have remained, even after cleaning with a brush cleaner. This has caused reduced yields, the need for re-work, processing delays and increased manufacturing cost. Accordingly there is a need for an improved method for removal of embedded particles during chemical mechanical polishing.

BRIEF SUMMARY

[0007] By way of introduction only, a chemical mechanical polishing method and apparatus are introduced that reduce embedded particles during CMP processing. Throughout the CMP process, the wafer-carrier and the polish platen turn or rotate in the same direction. This enables particles to become embedded in the oxide or other film surface. In the disclosed process, during a final polish step, the wafer carrier or polish platen is turned or rotated in the opposite direction. Embedded particles are then pulled out of the oxide or film, creating a much cleaner wafer.

[0008] The foregoing summary has been provided only by way of introduction. Nothing in this section should be taken as a limitation on the following claims, which define the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a top view of a chemical mechanical polishing (CMP) system;

[0010] FIG. 2 is a front elevation view of the CMP system of FIG. 1; and

[0011] FIG. 3 is a flow diagram illustrating a method for operating the CMP system of FIGS. 1 and 2.

DETAILED DESCRIPTION OF THE DRAWINGS AND THE PRESENTLY PREFERRED EMBODIMENTS

[0012] Referring now to the drawing, FIG. 1 shows a top view of a chemical mechanical polishing (CMP) system and FIG. 2 shows a front elevation view of the CMP system 100 of FIG. 1. The CMP system 100 is exemplary only and in the drawing is greatly simplified in order to emphasize certain operational aspects of the system 100. It is to be appreciated that in other embodiments, many modifications, additions, deletions and rearrangements may be made while still providing the benefits described herein.

[0013] The CMP system 100 includes a platen 102, a wafer carrier 104, a platen drive system 106, a wafer carrier drive system 108 and a control unit 110. The platen 102 is configured for mounting a polishing pad 112. The wafer carrier 104 is configured to retain a semiconductor wafer 114 during a chemical mechanical polishing process. During the CMP process, the polishing pad 112 polishes a surface 116 of the semiconductor wafer 114 when the wafer carrier 104 and the platen 102 are brought into proximity.

[0014] The platen drive system 106 is mechanically coupled with the platen 102 to rotate the platen 102 and the polishing pad 112 in one of a first rotational direction and a second rotational direction. In the top view of FIG. 1, the first rotational direction may be referred to as clockwise and the second rotational direction may be referred to as counter-clockwise. Some embodiments may not permit two-way rotation of the platen 102 and the polishing pad 112 in both the clockwise and counter-clockwise directions. In this regard, FIGS. 1 and 2 present the most general case. For embodiments with more limited rotational

functionality, the principles described generally herein may be readily adopted to accommodate the limitations.

[0015] The platen drive system 106 is coupled through a drive shaft 118 that rotates with the platen 102 about a center line 120. The platen drive system 106 generally includes a motor such as an electric motor for rotating drive shaft 118, the platen 102 and the attached polishing pad 112. The platen drive system 106 thus forms pad rotation means for rotating the polishing pad 112 relative to the rotation of the semiconductor wafer 114 to produce chemical mechanical polishing of the surface 116 of the semiconductor wafer 114. The pad rotation means may equivalently include a motor, transmission system with gears for varying the rotational speed of the platen 102 and a feedback control system for control of the rotational speed. In the illustrated embodiment, the platen drive system 106 is under control of the control unit 110.

[0016] The wafer carrier drive system 108 is mechanically coupled with the wafer carrier 104 to rotate the wafer carrier 104 and the semiconductor wafer 114 in one of the first rotational direction and the second rotational direction. As shown in FIG. 1, the semiconductor wafer 114 may be rotated in a clockwise direction or a counterclockwise direction. Some embodiments may not permit two-way rotation of the wafer carrier 104 and the semiconductor wafer 114. Thus, FIGS. 1 and 2 present the most general case. For embodiments with more limited functionality, the principles described generally herein may be readily adopted to accommodate the limitations.

[0017] The wafer carrier drive system 108 is coupled through a drive shaft 112 that rotates with the wafer carrier 104 about a center line 122. The wafer carrier drive system 108 generally includes a motor such as an electric motor for rotating the drive shaft 112, the wafer carrier 104 and the attached semiconductor wafer 114. The wafer carrier drive system 108 thus forms wafer rotation means for rotating the semiconductor wafer 114 in one of the first direction and the second direction in the CMP system 100. The wafer rotation means may equivalently include a motor, transmission system with gears for varying the rotational speed of the wafer carrier 14 and a feedback control system for control of the rotational

speed. In the illustrated embodiment, the wafer carrier drive system 108 is under control of the control unit 110.

[0018] The control unit 110 in one embodiment includes a microcontroller for monitoring and controlling operation of the CMP system 100. The microcontroller of the control unit 110 operates in response to data and instructions stored in a memory of the control unit 110 and in response to conditions sensed about operation of the CMP system 100. The control unit 110 may further include a user interface for providing direct user control of portions of the CMP system 100. The control unit 110 may further include a system interface for providing automated control of the CMP system 100 by remote data processing systems and for data logging.

[0019] The control unit 110 is electrically coupled to the platen drive system 106 and the wafer carrier drive system 108 for controlling these respective systems. By providing appropriate digital or analog control signals to the platen drive system 106 and the wafer carrier drive system 108, the control unit 110 may control the direction of rotation and the speed of rotation of the platen 102 and the wafer carrier 104 over time, including the time duration of CMP processing steps. In alternative embodiments, the control unit 110 may communicate with either the platen drive system 106 or the wafer carrier drive system 108 or both over a data communication bus, sending and receiving data and commands to the remote units.

[0020] The control unit 110 thus forms control means for controlling at least one of the wafer carrier drive system or other wafer rotation means and the platen drive system or other pad rotation means. Operating as a control means, the control unit generates the necessary control signals or data command to produce a first relative rotation during a first polishing duration and producing an opposite relative rotation during a second polishing duration. In the illustrated embodiment, the first relative rotation is rotation between the wafer carrier and the polishing pad in opposite directions, and the opposite relative rotation is rotation between the wafer carrier and the polishing pad in the same direction.

[0021] It is to be noted that other embodiments may include more than a single wafer carrier such as wafer carrier 104. The multiple wafer carriers are positioned generally around the perimeter of the polishing platen 102 so that multiple semiconductor wafers may be processed simultaneously. This improves system throughput. Other modifications or extensions may be made as well.

[0022] The embodiment of FIGS. 1 and 2 and similar embodiments may be used to remove embedded particles introduced in the surface of the semiconductor wafer 114 during a CMP process. By removing such particles during a final polish process reduces the need for rework of wafers in process and reduces defectivity which causes yield loss.

[0023] It has been noticed that, due to the wafer carriers and polish platens in CMP systems turning consistently in the same direction during the primary CMP polish process, particles become embedded in the film which forms the surface of the semiconductor wafer being polished. In accordance with the presently disclosed embodiments, during a final polish process, the polishing platen or the wafer carrier is turned or rotated in the opposite direction relative to rotating during the primary CMP polish process. Particles embedded in the film of the surface are pulled out of the film by the reverse-polishing process. This results in a cleaner wafer with less defectivity caused by particle scratching or other CMP processes.

[0024] In the embodiment illustrated in FIGS. 1 and 2, the primary polish process and the final, reverse polish process are performed using the same CMP system 100. Initially, a semiconductor wafer such as the wafer 114 is loaded in a wafer carrier such as wafer carrier 104. During a first processing phase, the semiconductor wafer in the wafer carrier is rotated in a clockwise direction and the polishing pad is rotated in a counter-clockwise direction for a predetermined period of time. During a second processing phase, the semiconductor wafer in the wafer carrier is rotated in a counter-clockwise direction during a final polish duration.

[0025] In alternative embodiments, the respective rotation directions may be varied. If the primary polishing process turns the polishing pad counter-clockwise

and turns the wafer carrier clockwise, during the reverse polishing process, the polishing pad will be turned clockwise and the wafer carrier will be turned clockwise. Other possibilities are equivalent. For example, in some CMP systems, the polishing pad and the wafer and wafer carrier are conventionally rotated in the same direction, rather than in opposing directions as described above in connection with FIGS. 1 and 2. During the final polish process, one of the platen and the wafer carrier is reversed in rotation direction so that the reverse polishing process will pull contaminant particles from the surface of the semiconductor wafer.

[0026] The predetermined period of time for the primary polish process and the final polish duration for the reverse polishing process are preferably controlled by the control unit 110 so that the processes may be automated. Alternatively, either phase may be manually controlled. The predetermined period of time for the primary polish process may be any suitable amount of time, such as in the range of ten minutes. The final polish duration is generally shorter, such as less than a minute, since this processing phase is intended primarily to remove embedded particles rather than to polish or planarize the wafer.

[0027] The direction of rotation of either the platen or the wafer carrier may be reversed by any suitable technique. A transmission system of either the wafer carrier drive system 108 or the platen drive system 106 may be adjusted to reverse the rotation direction, such as selecting a reverse gear. Alternatively, the motor of either the wafer carrier drive system 108 or the platen drive system 106 may be adjusted to reverse motor rotation. Any suitable rotation speeds may be used.

[0028] The CMP system 100 of FIG. 1 further includes a spray nozzle 126 for introducing liquid onto the polishing pad 112 to remove particles from the polishing pad. The liquid may be deionized (DI) water, slurry or other pad conditioning material. Preferably, the spray nozzle 126 directs a high pressure spray at the polishing pad to dislodge and remove the particles from the pad surface so that the particles are not re-introduced to the surface of the semiconductor wafer 114.

[0029] FIG. 3 is a flow diagram illustrating one embodiment of a method for removing embedded particles introduced during chemical mechanical polishing in a CMP system. The method of FIG. 3 begins at block 300.

[0030] At block 302, one or more semiconductor wafers are loaded on wafer carriers at a load station of the CMP system. As noted, a single wafer may be processed or, to increase system throughput, multiple wafers may be loaded and processed substantially simultaneously.

[0031] At block 304, the CMP polishing process begins. During a primary polish phase, the wafer in the wafer carrier is rotated in a first direction and brought in contact with the polishing pad which is rotating in a first direction. The wafer rotation direction and the polishing pad direction may be the same direction or may be different. Speed of rotation and duration of the primary polish phase may be set suitably to accomplish the goals of the CMP process for the film being polished. For example, if a relatively hard film is being planarized, a longer primary polish duration will be required.

[0032] At block 306, the relative direction of rotation between the semiconductor wafer and the polishing pad are reversed. This is done, for example, by reversing the drive system for either the wafer carrier or the polishing platen in any suitable manner. The result is that the relative direction in which the surface of the semiconductor wafer is moving past the surface of the polishing pad is reversed, so that a reverse polishing action is imparted on the surface of the wafer, tending to pull embedded particles from the wafer surface. Because the relative sizes and rotation directions of the polishing pad and the wafer may vary from embodiment to embodiment, a key goal for any embodiment is implementation of a reverse polishing process when the relative direction of the two moving surfaces are reversed. This tends to counter the bias introduced by the continuous forward polishing process and to dislodge and remove any particles including sticky particles introduced in the wafer surface.

[0033] In some embodiments, while the reverse polishing process occurs at block 306, a high pressure nozzle is activated to spray liquid on the polishing pad. This liquid may be DI water or other material. The liquid serves to dislodge and

wash away from the polishing pad contaminant particles which have been removed from the surface of the wafer so that the particles can not recontaminate the wafer surface.

[0034] The duration of the reverse polishing process may be any suitable time, but generally only a short time such as under a minute is required. At block 310, the wafer or wafers are unloaded from the CMP system. The method ends at block 312.

[0035] From the foregoing, it can be seen that the present embodiments provide method and apparatus for reducing surface particle contamination of semiconductor wafers during CMP processes. After a primary polishing operation, a relatively brief reverse polishing process is introduced to remove contaminants including even sticky particles from the surface of the semiconductor wafers. This process can dramatically reduce defectivity and particle damage caused during CMP processes. This substantially reduces manufacturing cost as the manufacturing yield increases. The cost is minor, only a single additional step which can be readily automated with modifications to existing equipment. The process may even reduce the time necessary to clean CMP equipment and the wafers themselves due to cleaner wafers coming from the CMP tools.

[0036] It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.